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Assessment the role of snow in hydrological cycle of the Borjomula-Gudjareti-Tskali rivers basin

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Abstract

During study summarizing exiting meteorological, hydrological and snow data in the studied area, installation of the monitoring network, collection of water samples, snow expeditions and a more detailed sampling during snowmelt. Regular monitoring consists of precipitation, air temperature and humidity measurements at 3 sites, and water level measurements at 2 rivers. Monthly samples for isotopic analyses (stable water isotopes) are collected from 3 raingauges, 2 rivers, 1 borehole and 2 springs since. The network build in the project provided a lot of new data on snow hydrology in the studied area that was not available before. Measurements at different altitudes were useful. Although snowfall represents just about 30% of annual precipitation, snowmelt water is an important source of water for the rivers (maximum contribution about 50%). Snowmelt affects river runoff at least 2-3 months. Yet, stable water isotopes in the snowmelt water significantly differ among the sites and they are different from those in the snow cover.

Study area

Investigation was caring out in the frame of IAEA project. Studied area (Fig. 1) is situated in the southwestern part of Georgia, in the Little Caucasus Mountains, the Adjara-Trialeti range. It is drained by two main rivers, namely the Gudjareti-Tskali river (catchment area 316 km^2, its mean altitude is 1700 m) and the Borjomula river (catchment area 168 km^2, mean altitude 1600 m). The rivers are the right-hand tributaries of the Mtkvari (Kura) river which is the most important transboundary river in the region of Georgia and Azerbaijan. Apart from the mountains surrounding the study area, the dominant geological unit is the lava body forming the plateau between the two rivers. The Borjomula and Gudjareti rivers flow in their middle and lower sections in narrow valleys (1, 2).

The altitude ranges from about 800 m a.s.l. at the Borjomi city to about 2900 m a.s.l. at the highest mountain peaks. Mean annual mean air temperature is 8.3°C in Borjomi (altitude 794 m a.s.l.), 4.4 °C in Bakuriani (altitude 1703 m). Mean air temperatures of the warmest months (July, August) in Borjomi, Bakuriani and the slopes of the study area are 19°C, 14°C and 9-10°C, respectively. Mean air temperatures in January are 2.8, -5.5 and -9°C, respectively. Mean annual precipitation in the area varies from 650 to 950 mm in Bakuriani (3).

The objectives of the project are:

- Quantification of the amount and residence time of snowmelt water discharging into streams and recharging the captured springs
- Contributions of snowmelt water to stream flow in the Borjomula and Gudaretis-Tskali rivers
- Groundwater recharge from the snow (springs/ boreholes at Daba, Sadgeri and Tba)

Sampling methodology

There was no network providing climatic and hydrological data for the studied area. Therefore, it had to be established within this project from December 2010. Since the study area is mountainous, the network attempts to describe altitudinal evolution of main climatic characteristics. That way, monitoring station was installing on the several place:

- Monthly composite samples of precipitation are collected in Hellman raingauge and air temperature and air humidity data (hourly time interval) measured by the HOBO sensor, at 3 elevations- Tsagveri, Tba (new station) and Bakuriani (existing station).
- Two gage was installed at the Borjomula and at the Gudjareti river equipped with the pressure transducer (HOBO diver, hourly measurements).
- Isotopic sampling on monthly step carried out on the this two rivers and 2 springs Daba and Sadgeri. Also, on the Tba boreholes.
- Snow course measurements (SD, SWE) at 5 locations (elevations), along with samples for isotopes
- Snowmelt water sampling at 3 locations-Tba, Bakuriani and Tsagveri (extended funnel gauge, plastic and tin snow lysimeters, passive (Frisbee) samplers at 1 location-Tba)

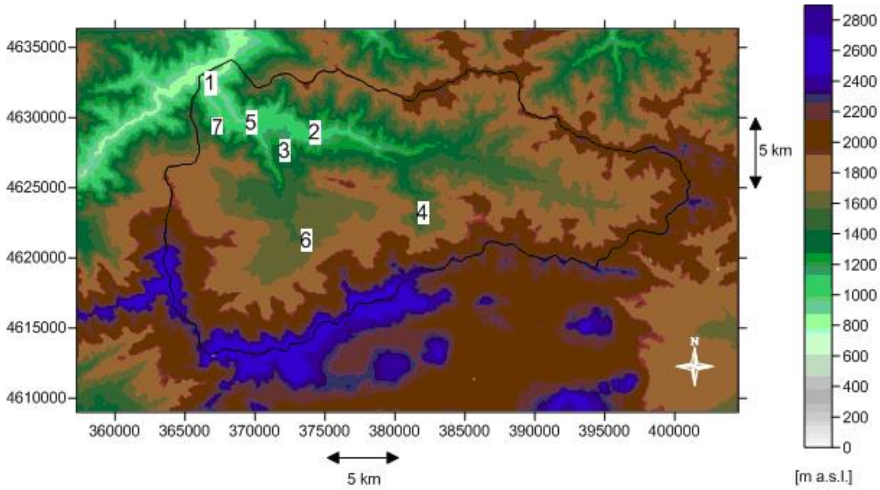

Fig. 1. Monitoring and sampling points in the studied area.

This figure 1 shows digital elevation model and the network. WS stands for water stage measured on the rivers, P and T are precipitation and air temperature measurements, respectively. SWE denotes the sites where we measure snow depth and water equivalents at snow courses. SLYS is the abbreviation for snowmelt lysimeters where we sample water from melting snow that is consequently analyzed for stable water isotopes (4).

Stable water isotopes are analyzed by the LGR isotope analyzed in Prague

Monitoring results

During monitoring period (33 months) found out very good correlations between air temperature variations among sites. Air temperature at different altitudes was very well correlated. The data confirm that winter 2013 was warmer and negative temperatures lasted shorter than in winter 2012. At Tsagveri and Tba stations we have observers the solid precipitation represents about one third of annual precipitation. Annual precipitation is relatively small considering mountain character of the area. Number of days with precipitation at the highest altitude is significantly higher than at lower altitudes.

Water pressure data revealed that runoff regime of both rivers is the same.

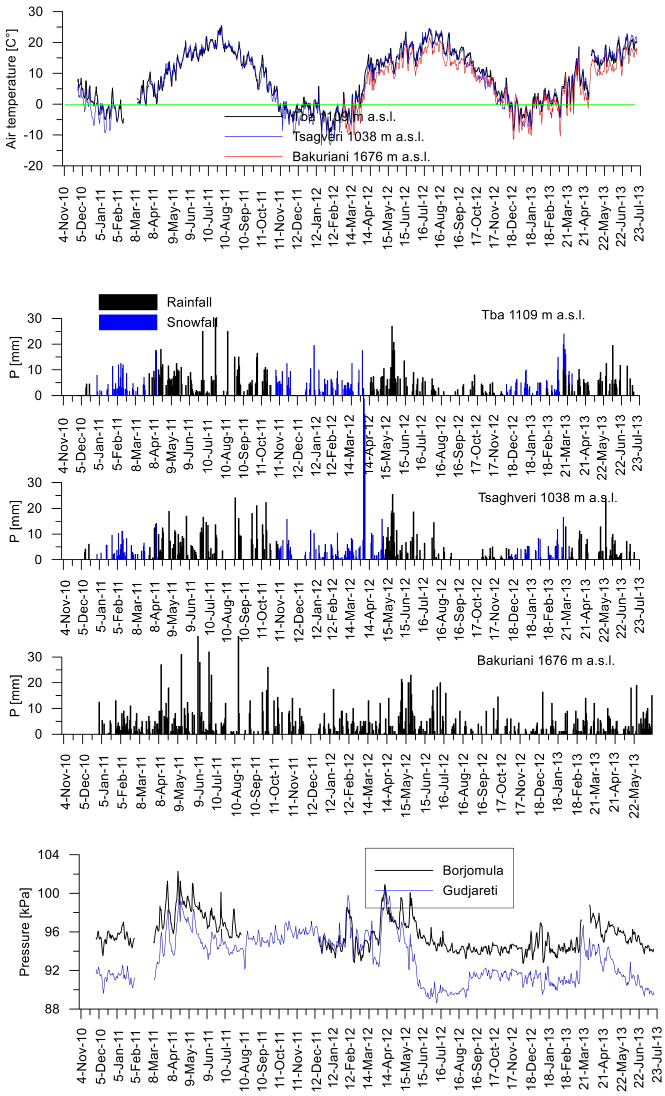

Fig 2 Snowmelt periods

Combined figure of climatic conditions and runoff regime indicates that snowmelt period in 2011 lasted approximately from 11 March to the beginning of June. Snowmelt in 2012 started later (at the end of March) to the end of May. Snowmelt period in 2013 was same, started approximately in the mead part of March to the end of May.

We measured snow courses on the 5 sites at altitudes 952-1676 m a.s.l., measured 4 times in 2011, 5 times in 2012 and 2 time in 2013, SWE gradients about 4-9 mm/100 m, significantly less snow in forest. SWE exhibited altitude gradients of about 5 mm of SWE per 100 meters of altitude. However, the gradients are applicable only until the beginning of snowmelt.

Measurements of snow water equivalents in 2011 covered mostly the snow accumulation period, measurements in 2012 and 2013 covered also the snowmelt period. Measured maximum of snow water equivalent varied from about 120 to reached about 180 mm.

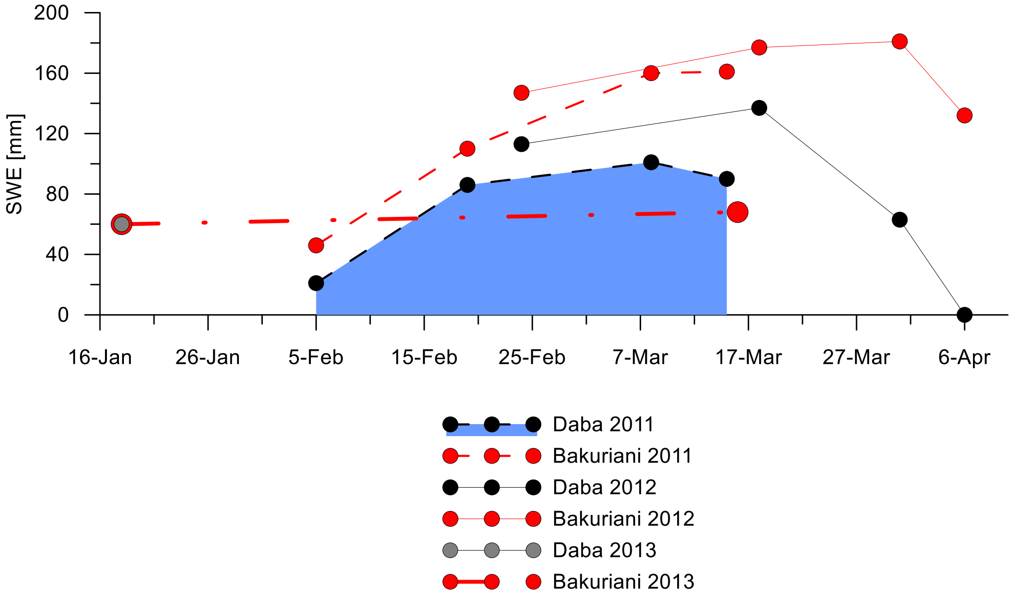

Fig 3 Snow Water equivalent

Fig 3 show, that, maximum SWE in the lower part of the study area represented about 60-80% of solid precipitation. The duration of the melting period varies between 2-3 weeks.
This figure #4 shows spatial variability of deuterium in precipitation at different altitudes, rivers and groundwater. We present also longer data series from GNIP station in Bakuriani and GNIR station on Mtkvari very close to the study area. The data at this step indicate appearance of lighter water in the streams and groundwater in spring.

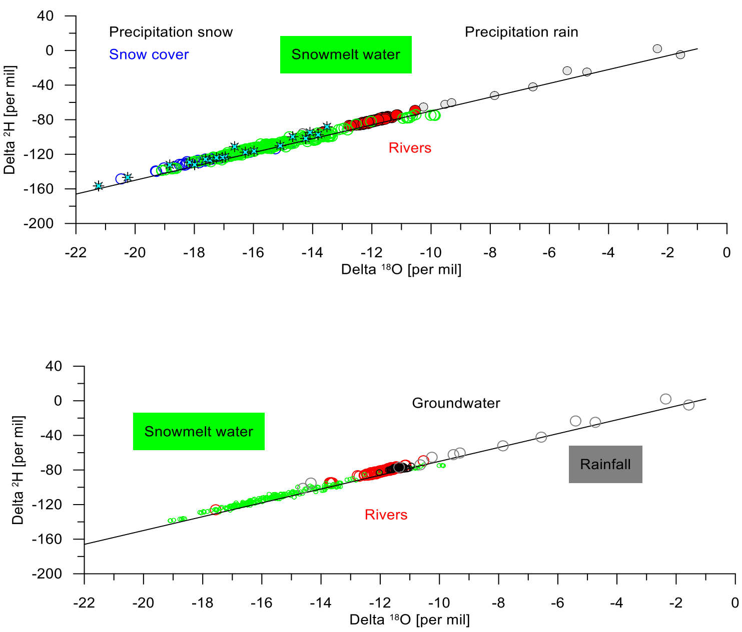

Fig 4 Isotopic composition of water

Groundwater does not differ from the rivers. It indicates that both the rivers and shallow groundwater come from the same source. As expected, the groundwater is generally isotopically heavier than river water.

Snow cover during the snowmelt becomes isotopically enriched.

Data in spring 2011 show that air temperatures increased approximately around the middle of March, but a more intensive snowmelt started a few days' later Water levels in the rivers increased as a response to the snowmelt and later the typical snowmelt runoff regime (diurnal variability of runoff) evolved.

Isotopic composition of snowmelt water sampled at Bakuriani by means of the smaller tin and the larger plastic lysimeters were mostly similar, except the beginning of the snowmelt period.

Snowmelt water at Tsagveri (lower altitude) during more intensive snowmelt was isotopically lighter than at Tba (higher altitude, but more exposed to sunshine radiation).

River water reacted to increased snowmelt input in the middle of March, following rainfall on March 19 and continuation of snowmelt since March 26.

Because the isotopic composition of infiltrating snowmelt water at different sites and times significantly varied, a range of values was used in hydrograph separation.

Hydrograph separation in spring 2011 for the Borjomula river. Maximum calculated contribution to total runoff was 21%. Snow contributions to runoff in the Gudjareti River were a higher.

In 2012 intensive snowmelt started at the beginning of April (about 2 weeks later than in warmer winter of 2011).

Sampling at Bakuriani confirmed the finding from 2011 that at the beginning of snowmelt the isotopi composition of snowmelt water samples by plastic and tin lysimeters significantly differed.

Isotopic composition of snowpack was relatively similar to that of snowmelt water.

In 2013 snowmelt started at the end of March and finished at the end of May.

Conclusions

- The network build in the project provided a lot of new data on snow hydrology in the studied area that was not available before (solid-liquid precipitation, hourly variability of water levels in the rivers, snow cover characteristics, SWE modelling, stable water isotopes, snow-covered area from MODIS)
- Measurements at different altitudes were useful
- Although snowfall represents just about 30% of annual precipitation, snowmelt water is an important source of water for the rivers (maximum contribution about 50%)
- The importance of snow is indicated also by the overall distribution of isotopic composition of waters
- Snowmelt affects river runoff at least 2-3 months
- Snowmelt is thus important also for water availability in dry summer period
- Isotopic composition of snow cover does not show an altitude gradient
- Yet, stable water isotopes in the snowmelt water significantly differ among the sites and they are different from those in the snow cover
- Method of snowmelt water sampling influences the obtained data on stable water isotopes (perhaps also a consequence of the small-scale differences in isotopic composition of the snowpack)

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Исследование роли снега в гидрологическом цикли в басейнах рек Воржомула Гуджаретис-Цкали

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Резюме

Исследование посвящено изучению оценки роли снега в гидрологическом цикле. Во время изучения обобщены и уточнены метеорологические, гидрологические данные, данные о снеге в изучаемой области, создана сеть наблюдений, осуществлен сбор образцов воды, снега и другие образцов в период таяния снегов впериод март-май 2013. Регулярный мониторинг включает измерение осадков, температуру воздуха и влажности в 3-х точках наблюдения (высота 1038, 1109, 1676 метров над уровнем моря), а также измерение уровня воды в 2-х реках. Ежемесячные образцы для изотопного анализа были отобраны с 3-х дождемеров, 2-х рек, 1-й скважины и 2-х источников. Сеть наблюдений, созданная в рамках проекта, обеспечила многими новыми и ранее недоступными данными о гидрологии снега в изучаемой области (атмосферние осадки осадки, почасовые изменения уровня воды в реках, характеристики снежного покрова, SWE-моделирование, стабильные изотопы воды,). Измерения на различных высотах было полезными. Несмотря на то, что снегопады обеспечивают только примерно 30% годовых осадков, талая вода является важным источником воды для рек (максимальный вклад около 50%). Таяние снегов влияет на речной сток 2-3 месяца. Отметим, стабильные изотопы в талых водах значительно отличаются на местах и отличаются от снежного покрова.

თოვლის როლის განსაზღვრა წყალბრუნვის ციკლში ბორჯომულა გუჯარეთის წყლის მდინარეთა აუზებში

giorgi მელიქაძე, ნინო კაპანაძე, მარიამ თოდაძე

აბსტრაქტი

კვლევების მიზანს წარმოადგენდა თოვლის როლის განსაზღვრა წყლის ციკლში. კვლევების პერიოდში გაანალიზდა არსებული მეტეოლოგიური, ჰიდროგეოლოგიური და თოვლის საფარის მონაცემები. ხორციელდებოდა ექსპედიციები წყლის და თოვლის საფარის სინჯების აღების მიზნით. ორგანიზება გაუკეთდა სამონიტორინგო ქსელს ნალექების რაოდენობის, ჰაერის ტემპერატურის და ტენიანობის გადაზომად სამ სადგურში. ასევე, მდინარის დონის გაზომვებს ორივე მდინარეში. ყოველთვიურად ხდებოდა იზოტოპური სინჯების აღება 3 ნალექმზომიდან, 2 მდინარიდან, 1 ჭაბურღილიდან და 2 წყაროდან. მოპოვებული იქნა უახლესი მასალა თოვლის ჰიდროლოგიაში, რომელიც არ არსებობდა მანამდე. სხვადასხვა სიმაღლეზე განხორციელებული გაზომვები გამოდგა წარმატებული. თოვლის ნალექმა შეადგინა მთლიანი ნალექების მოცულობის 30%. ის წარმოადგენს მდინარეების მკვებავი წყლის მნიშვნელოვან წილს (მაქსიმალური წილი 50%). თოვლის დნობის შედეგად მდინარეების წყალუხვობა გძელდება 2–3 თვე. დადგინდა, რომ თოვლის ნადნობი წყლის იზოტოპური შემადგენლობა განსხვავდება სხვადასხვა სიმაღლეზე და ასევე, განსხვავდება თოვლის საფარის იზოტოპური შემადგენლობისაგან.